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WO 97/28327 A1 US 5357729 A US 4384802 A
US 4020202 A

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(54) Abstract Title
Structural truss

(57) A structural truss or frame comprises longitudinal support members of a fibrous composite, preferably carbon fibre, interconnected and received by nodal members (501). The nodal members (501) may receive a spigot attached to the support member, and the spigots may be ball-ended, to be received in a nodal socket (502) having the form of a spherical void. The spigots may be metallic, and may be retained at the end of a support member by an adhesive. The joint itself between the spigot and the socket (502) may be secured with an epoxy resin. The invention also relates to a method of assembling a truss from such components.

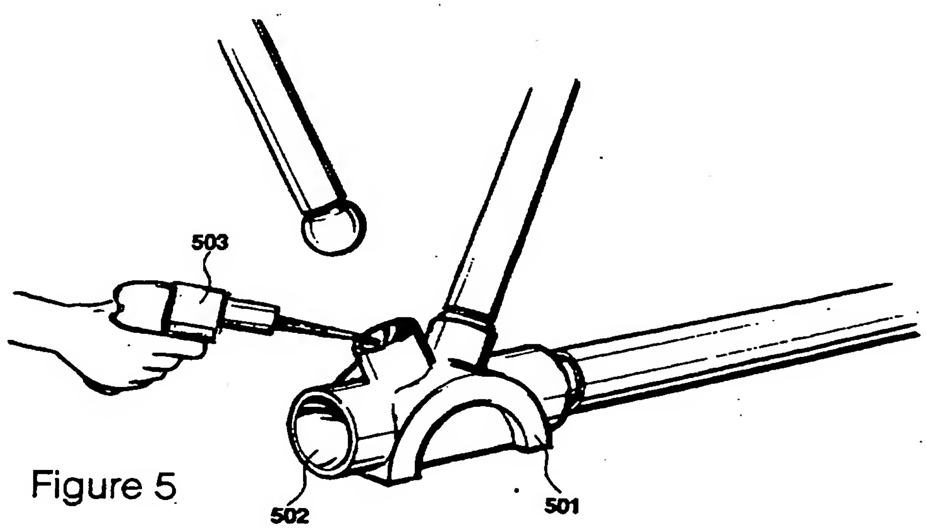

Figure 5

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

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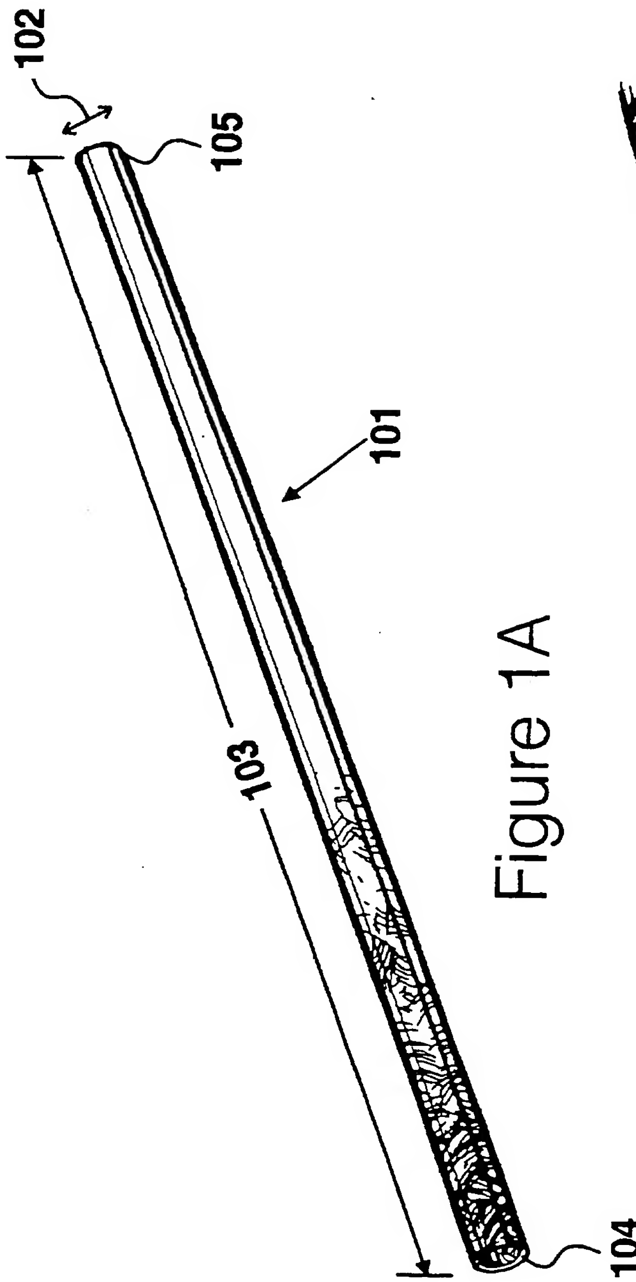


Figure 1A

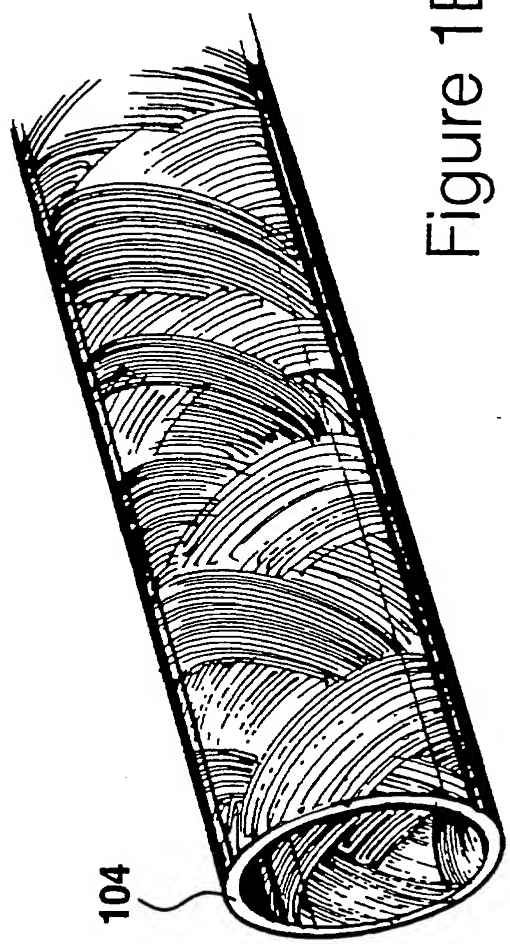


Figure 1B

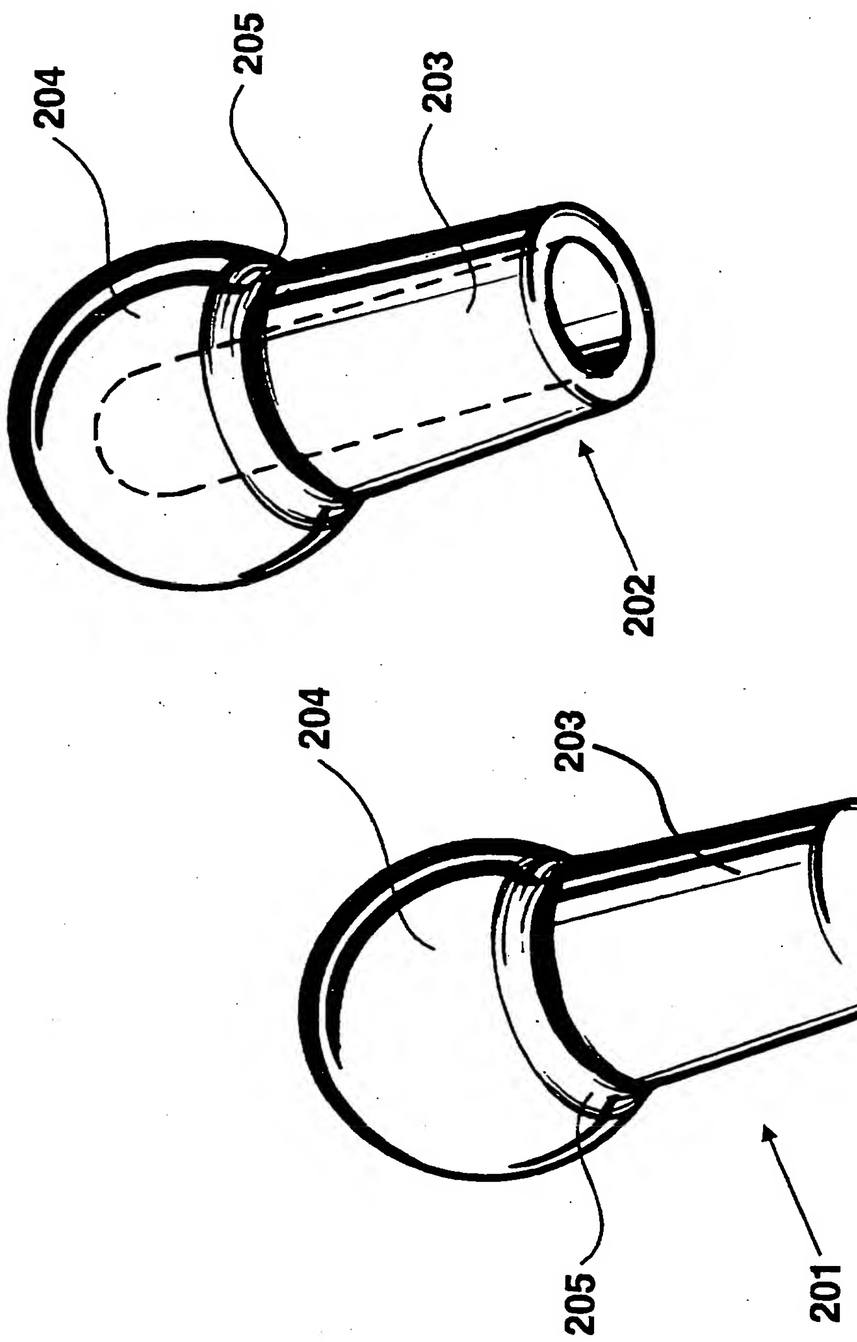


Figure 2

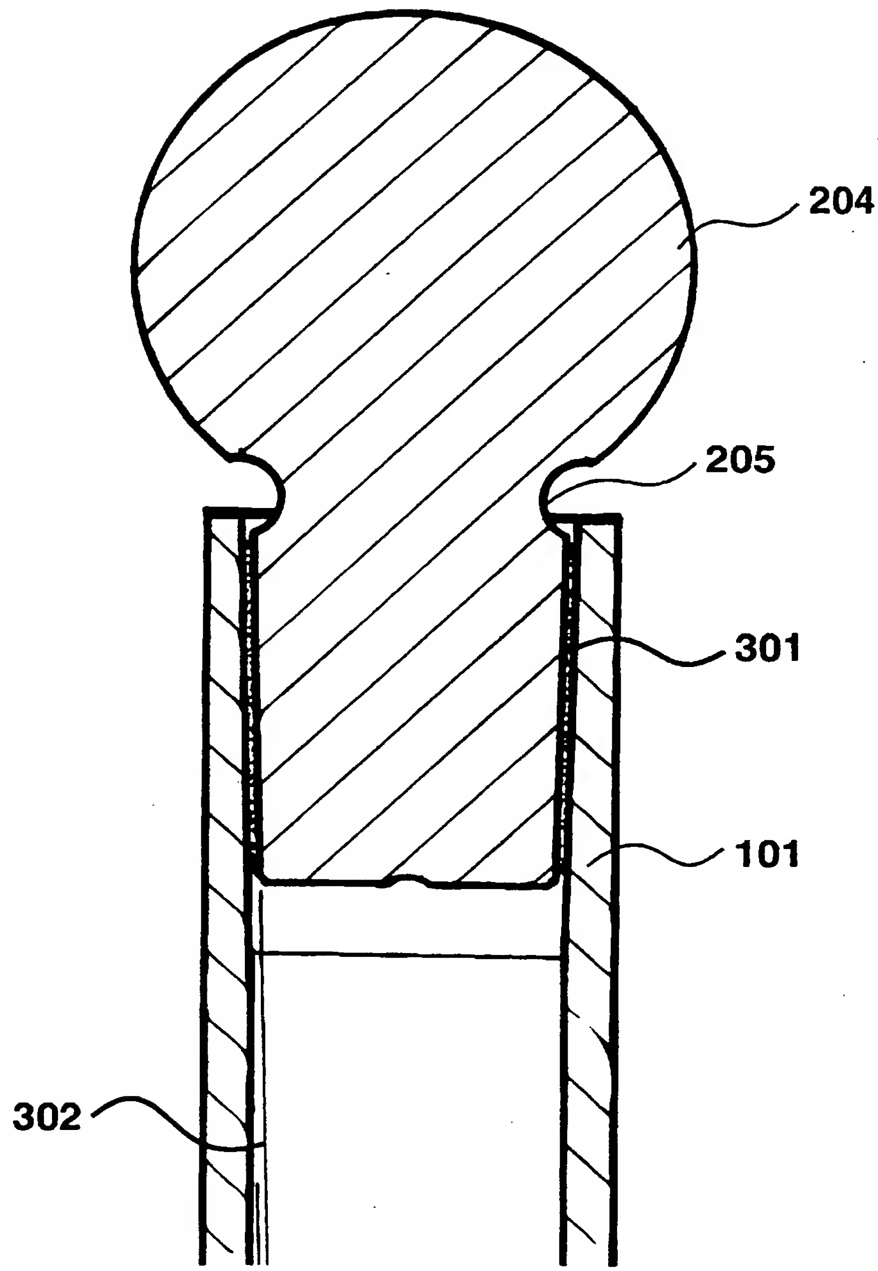


Figure 3

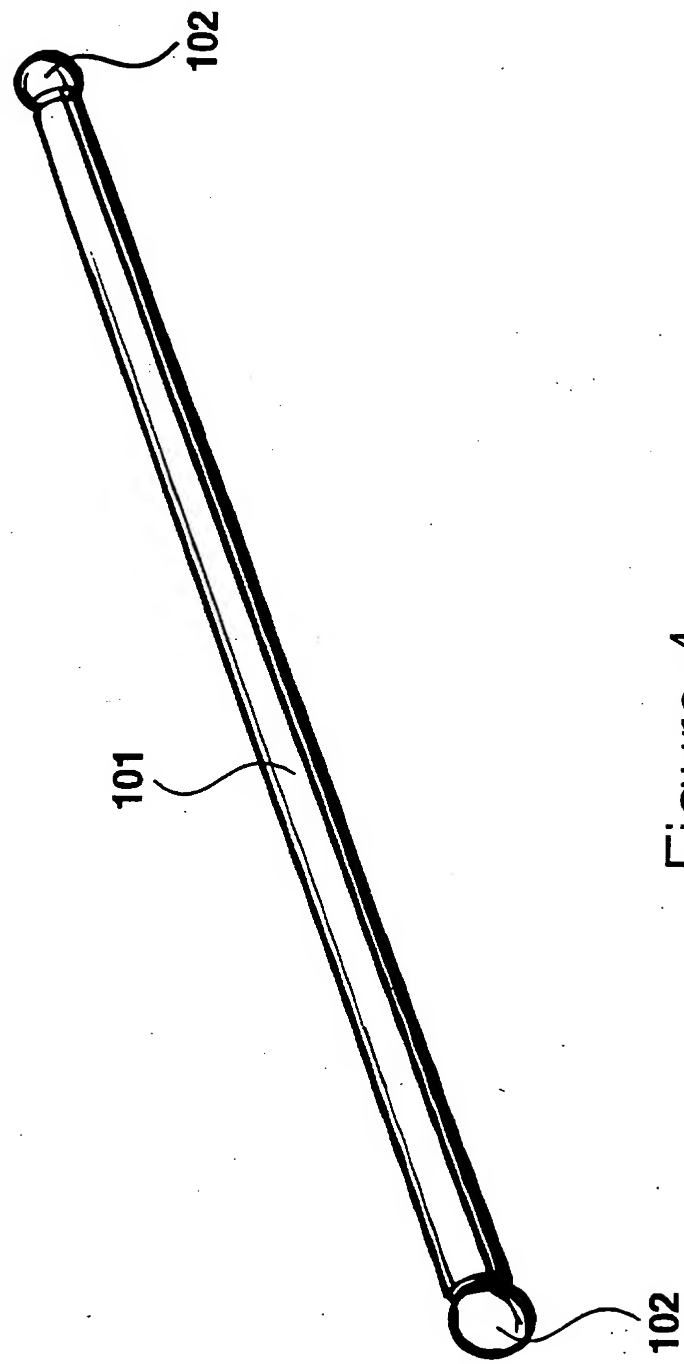


Figure 4

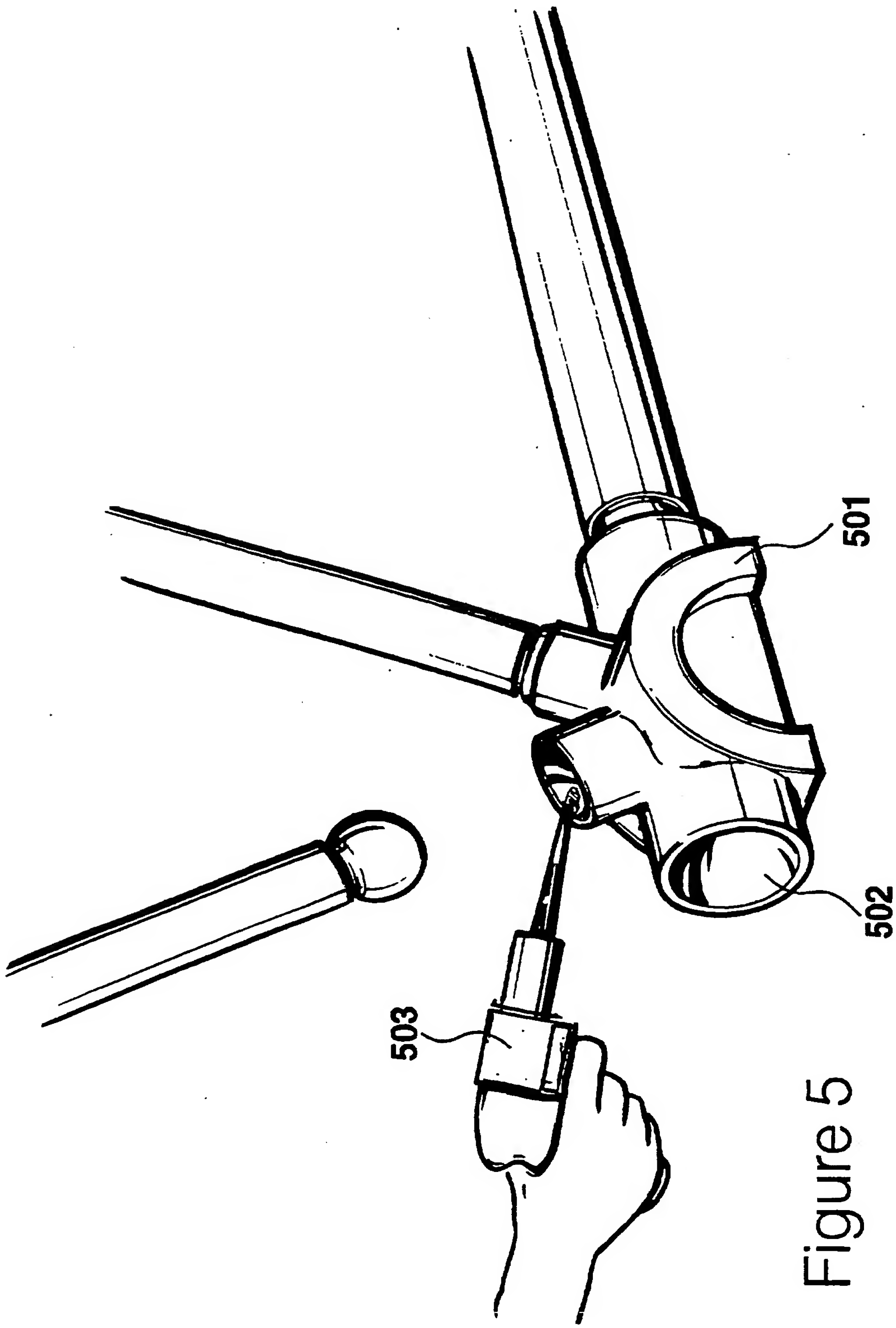


Figure 5

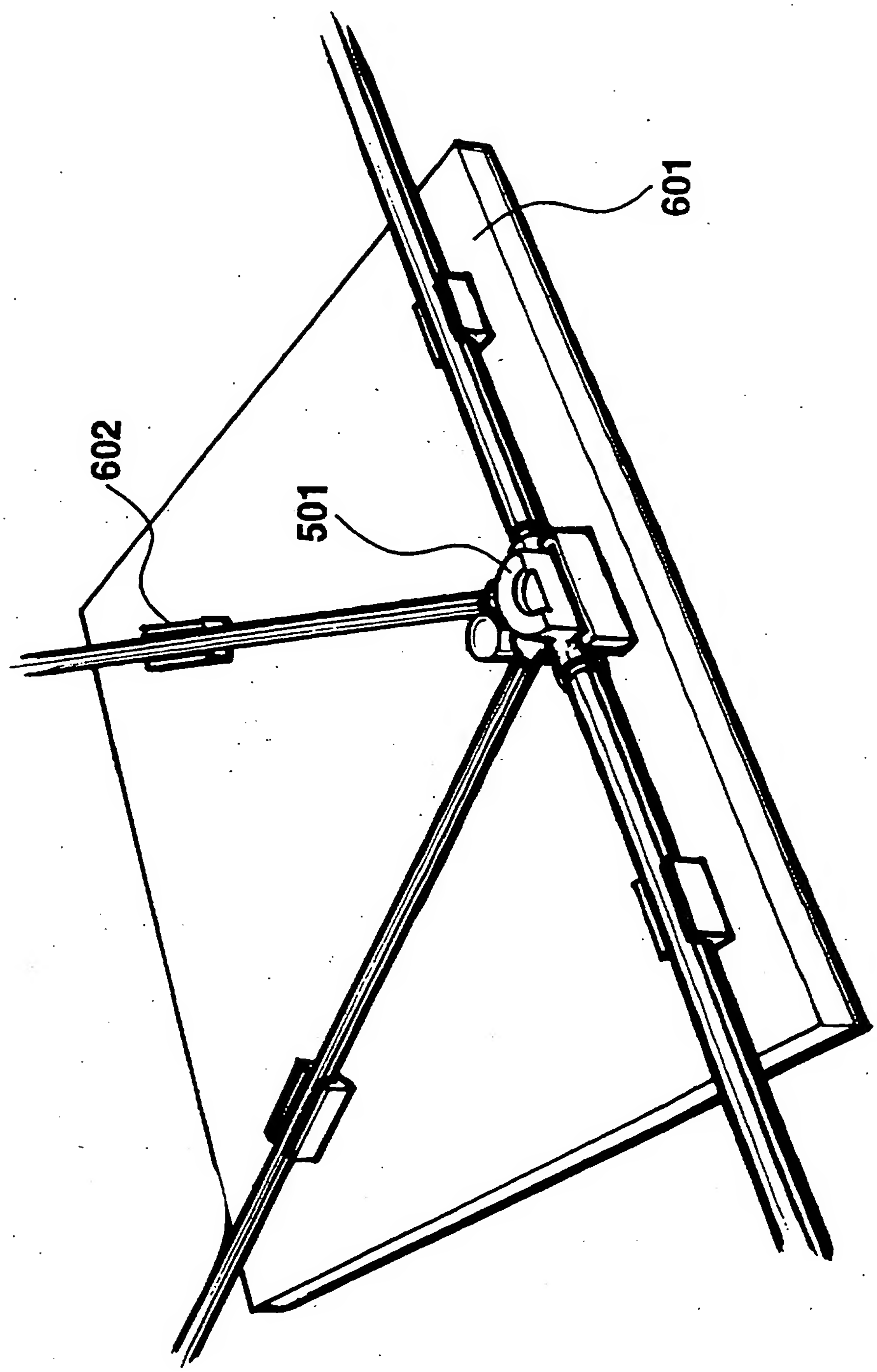


Figure 6

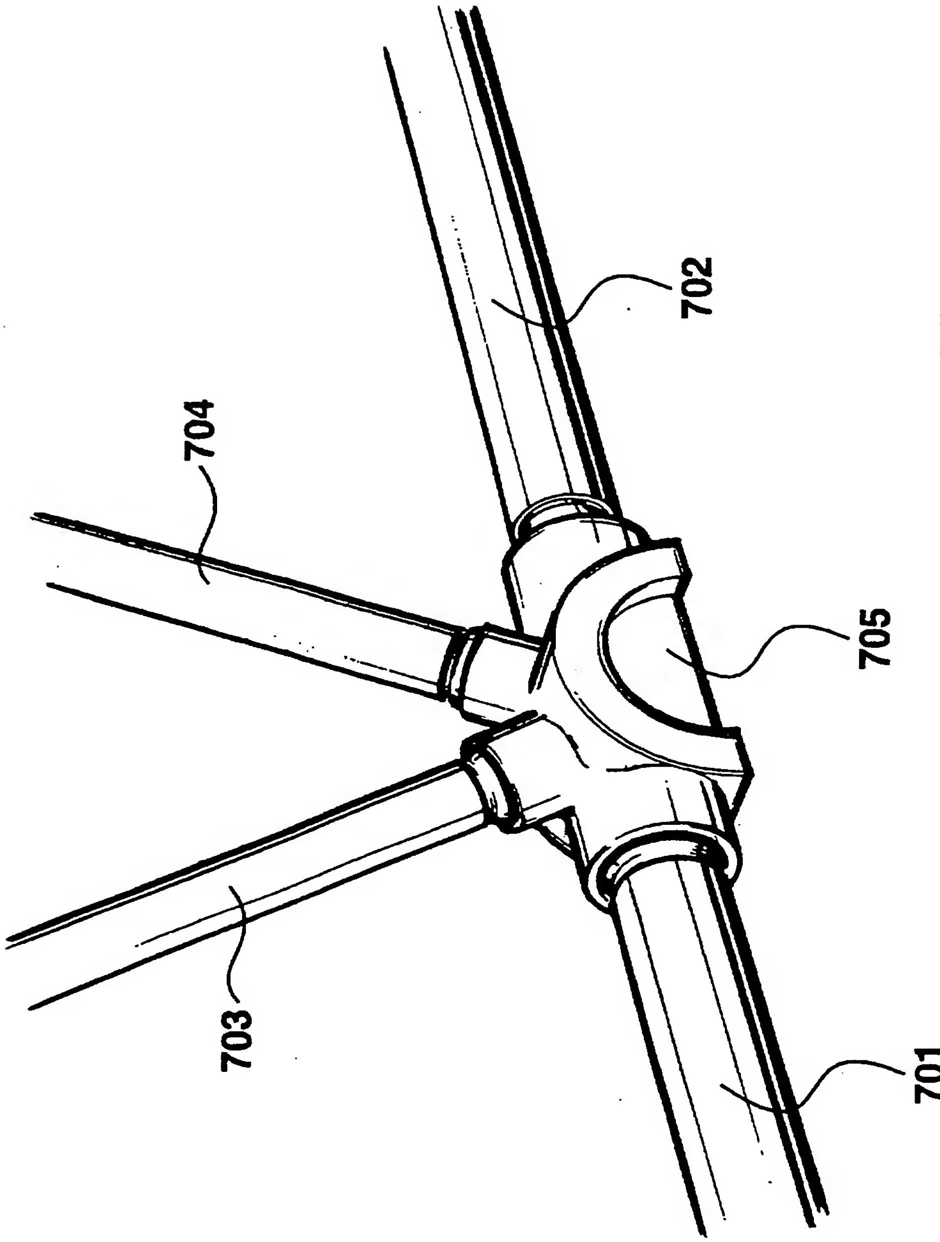


Figure 7

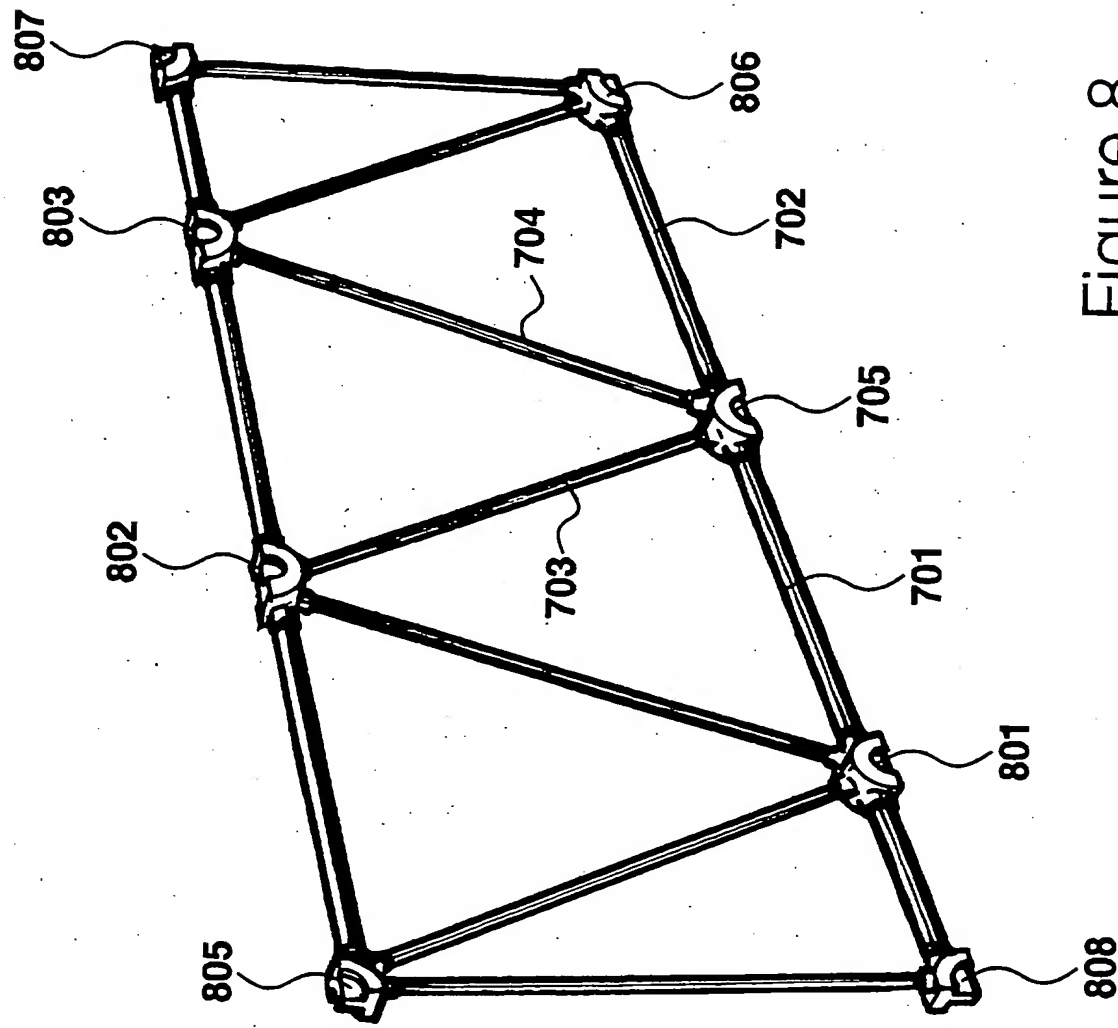


Figure 8

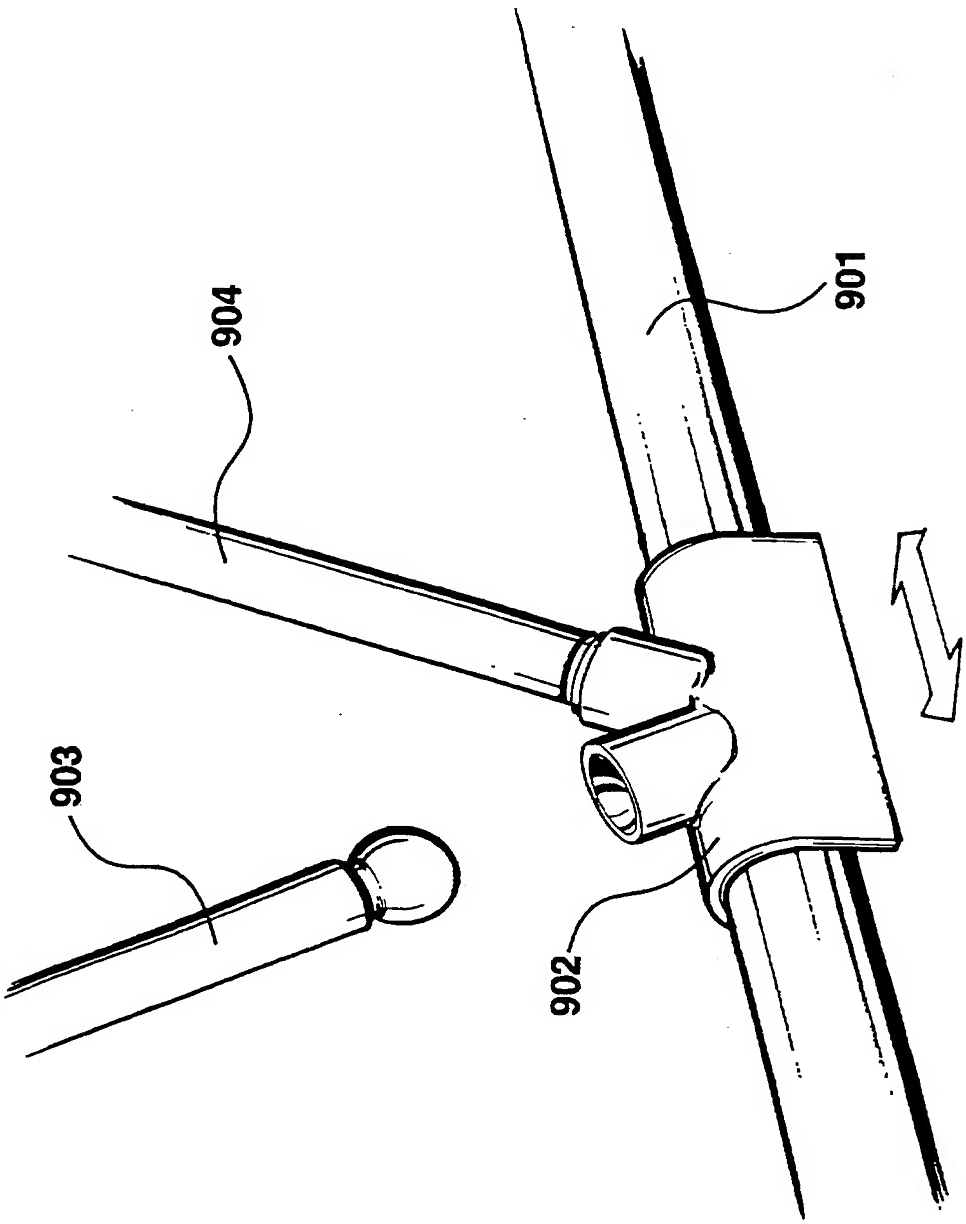


Figure 9

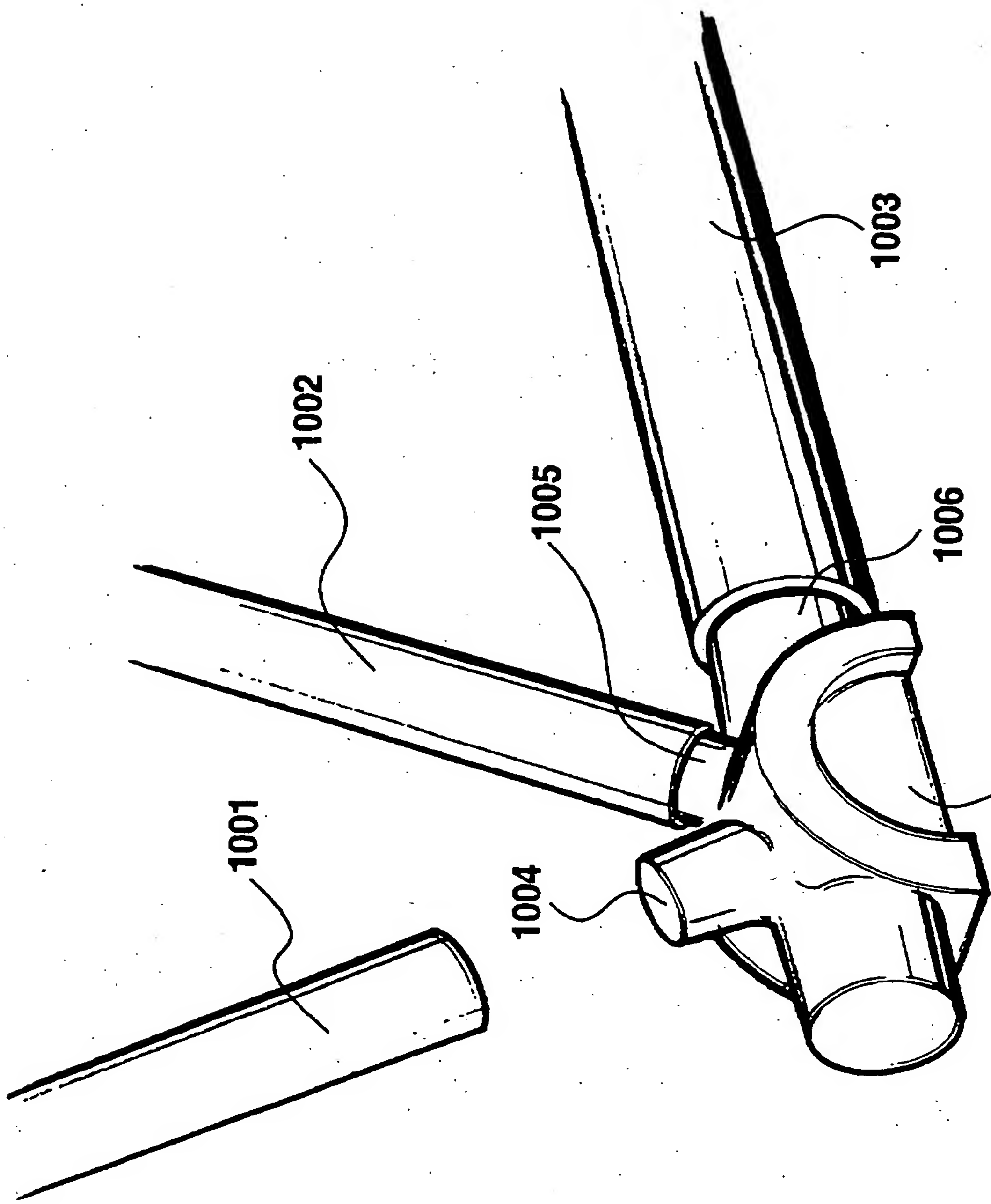
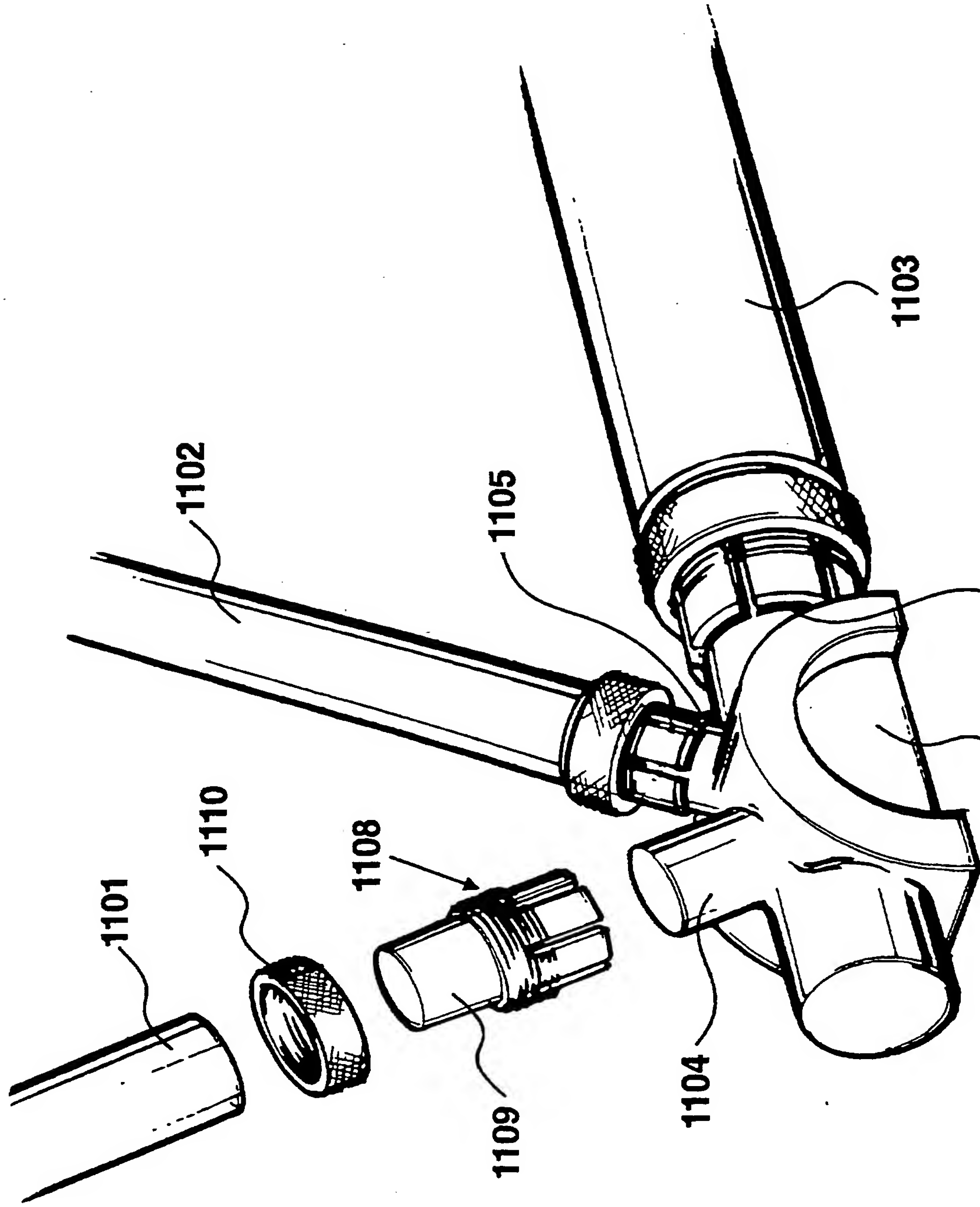


Figure 10

Figure 11



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STRUCTURAL TRUSS

The present invention relates to a structural truss or frame having a plurality of longitudinal support members held together by a plurality of nodal members.

Introduction

Structural trusses and methods for manufacturing structural trusses are well known and a significant amount of work has been directed towards developing new topologies and connection mechanisms.

Ultimately, architectural possibilities are limited by engineering constraints determined predominantly from the strength and durability of building materials. Thus, the design of any truss and the design of any space frame or similar structure employing such a truss will be limited by the strength and self weight of materials involved. Known lighter materials may have advantages but often these advantages are off-set by additional costs which has thus tended to direct designers to the more conventional materials, such as high tensile steel and high density aluminium alloys.

Fibrous composite materials, such as carbon fibre in combination with epoxy resin, are known. Materials of this type have been used in high performance, high value applications, such as in the construction of racing car bodies and military aircraft, where a whole monococque may be moulded and cured individually for each particular application. Carbon fibre monococques have known advantages and provide a very strong shell with significantly less weight than alternative previously employed materials, such as aluminium. However, a problem with constructing monococque arrangements of this type is that they are prohibitively expensive and only lend themselves to constructions of modest size.

Trusses and larger space frames and spans are often made from longitudinal extrusions of aluminium. In this way, the cost of a construction

may be reduced significantly given that it is fabricated from simple components, which may be transported in component form and then assembled on site. However, when using traditional materials such as high tensile steel, the structure tends to become heavy and cumbersome thereby significantly adding to constructional costs, while placing further constraints upon operators requiring mobile structures which may be required at a particular location for only a matter of days before being disassembled for application elsewhere.

Summary of The Invention

According to a first aspect of the present invention, there is provided a structural truss or frame having a plurality of longitudinal support members held together by a plurality of nodal members, wherein each of said support members is constructed from a fibrous composite material; and said nodal members are configured to receive said support members.

It is possible for the support members to be secured directly by the nodal members, in which the support members receive extensions from said nodal members. Alternatively, the support members may be secured to the nodal members by means of slotted collets. However, in a preferred embodiment, the support members have spigots attached thereto and said spigots are configured to be received by said nodal members. Preferably, said spigots are ball-ended and said ball-ends are received within spherical voids of said nodal members.

The support members may be fabricated by winding said fibrous material around a mandrill and the shape of said mandrill may be modified to produce appropriately cross-sectioned support members. However, in a preferred embodiment, the support members are substantially circular in cross-section. Preferably, the support members are hollow tubes which may be constructed from spiral wound carbon-fibre.

Many fibrous composite materials could be used for the construction but carbon-fibre provides a preferred option. Preferably, the fibrous material is bonded by an epoxy resin.

According to a second aspect of the present invention, there is provided a method of assembling a truss, comprising steps of winding carbon-fibres onto a mandrill with a resin to produce solid rods; cutting said rods to predetermined lengths; and securing said rods by nodal members such that some of said rods are placed in compression while some of said rods are placed in tension when said truss is in use.

In a preferred embodiment, the winding of said rods is adjusted in dependence upon whether said rods are to be placed in tension or compression.

Brief Description of The Drawings

Figures 1A and *1B* show a spiral wound carbon-fibre/epoxy tube;

Figure 2 shows ball-end spigots arranged to be secured to the tube shown in *Figure 1*;

Figure 3 shows a spigot of the type shown in *Figure 2* bonded into position within a tube of the type shown in *Figure 2*;

Figure 4 shows a basic assembly comprising a carbon-fibre tube of the type shown in *Figure 1*, having spigots of the type shown in *Figure 2* secured at either end;

Figure 5 shows basic assemblies of the type shown in *Figure 4* being secured to a node;

Figure 6 shows a node of the type shown in *Figure 5* secured within a jig so as to ensure the correct mounting of bonded basic assemblies;

Figure 7 shows the node of Figure 6 having a full complement of basic assemblies attached thereto;

Figure 8 illustrates a truss fabricated from a plurality of nodes of the type shown in *Figure 6*, with termination nodes for connection to other

trusses or assemblies;

Figure 9 shows an alternative embodiment in which the number of connections present is reduced by the use of a saddle-node;

Figure 10 shows a second alternative embodiment in which carbon-fibre tubes are connected directly to nodes without the use of ball-end spigots; and

Figure 11 shows a third alternative embodiment in which tubes are connected to nodes by means of detachable collets.

Detailed Description of The Preferred Embodiments

The invention will now be described by way of example only with reference to the previously identified drawings.

A spiral wound carbon fibre/epoxy tube **101** is shown in *Figure 1A*. Tube **101** has an outer diameter **102** typically ranging from 12mm to 300mm, which would be determined in response to a particular application. In the example construction shown herein, tubes having an outer diameter of 100mm and 150mm are employed, with a wall thickness of between 6 to 15mm.

End **104** of tube **101** is shown enlarged in *Figure 1B*. The tubes are bound on mandrills which determine the internal diameter of the tube with the total thickness of the tube being determined by the thickness of the windings, the number of windings and to a lesser extent the nature of the windings. In the example shown, the tubes have been wound in alternating directions at an angle of around forty-five degrees. The fibres have an external diameter of typically seventeen micro-metres and the resin system is an epoxy of the bi-phenol A/F type, post cured to provide maximum mechanical properties. Once cured, mechanical testing may be performed upon the tubes so as to confirm their mechanical strength, resulting in the calculation of moduli comparable with more conventional materials.

In the example shown in *Figure 1B*, the tube has been left with a wound surface finish, typical of small bore epoxy pipes. However, a glossy resin rich finish is preferably to improve weathering characteristics.

For most applications, a winding angle of forty-five degrees provides the optimum level of strength. By increasing the winding angle, with reference to the central axis, the fibres are brought more closely together along said axis resulting in the compressive strength characteristics of the tube being improved, at the expense of its tensile characteristics. Alternatively, windings made at an angle of less than 45 degrees with reference to the central axis, thereby laying more parallel with said central axis, having proved tensile characteristics, at the expense of their compressive strength.

Tube **101** is cut to a requisite length **103**, whereafter internal tapers are machined at either end **104**, **105**. Internal tapers **104**, **105** co-operate with spigots **201** or **202**, as illustrated in *Figure 2*. Spigot **201** is fabricated from drop-forged aluminium, whereas spigot **202** is fabricated from an injection moulded or cast plastic. Each spigot **201** includes a tapered portion **203**, a ball-end portion **204** and a circumferencial groove **205**.

Each internal taper **104**, **105** of a spiral wound tube **101** receives the tapered portion **203** of a spigot **201**, which is secured therein by epoxy glue or other bonding agent such as cyanocrylate. A taper angle of between two and five degrees is provided, with a preferred angle being three degrees. Thus, the tapered angle ensures that the spigot **201** is held firmly in place when pushed as far as it will go against the internal tapers of tube **101**. Spigot **201** is held firmly within tube **101** by means of a two-component epoxy resin, such as that supplied by CIBA Geigy. Preferably, the glue is of a low hysterisis type, ensuring that it is runny enough to cover all of the surfaces that are being glued together.

Glue technology of this type is now sufficiently advanced such that the glue weld is effectively as strong as the materials being bonded together. Furthermore, bonding times may be specified, typically ranging from seconds

to hours, so as to provide sufficient time for the assembly to be placed into position before the glue weld becomes secure.

A cross-section of a spigot **201** secured within a tube **101** is shown in *Figure 3*. The spigot **201** is held firmly in position by means of epoxy glue **301**. Furthermore, a three-degree taper, illustrated by angled line **302**, ensures that the spigot **201** is held firmly in position by tube **101**. Spherical insert portion **204** is received within spherical voids of nodes illustrated subsequently. Groove **205** provides assembly clearance thereby ensuring that the tube end effectively runs out before it can impinge upon the shoulders of the spherical portion **204**.

A basic assembly, consisting of a length of carbon fibre tube **101** with spigots **201** secured at either end is illustrated in *Figure 4*. As previously stated, the length of the assembly and its diameter could have many values, dependent upon a particular application. Similarly, the spigots **201** would be sized proportionally with the diameter of the tubes for which they are intended.

A truss is assembled from a plurality of basic assemblies **101**, connected by nodal members. A plurality of trusses may then be combined to form a complete construction. In simple trusses, all of the members may be of similar proportions. However, in most trusses, not all members are carrying similar forces and the size and durability of basic assemblies may be modified accordingly. Furthermore, by incorporating appropriately wound tubes **101**, account may be taken of estimated compressive, tensile and shear forces, so as to provide the requisite strength and rigidity while avoiding unnecessary weight and expense. It is also appreciated that by minimising weight and optimising the design, the overall level of forces contained within the structure are reduced, thereby facilitating additional improvements and enhancements which provide many advantages of varying importance depending upon the application of the finished construction.

A significant advantage of structures assembled from the carbon-fibre members disclosed herein is that the sizes of members required to provide a particular structure having a specified strength are significantly lower than equivalent structures fabricated from steel. Thus, for example in structures constructed using large areas of glass, the supporting members may be small and therefore become less visible allowing a larger proportion of the surface area to be perceived as transparent.

The surface finish of the structure is also noticeably different from that provided by similar metallic arrangements. In particular, it provides a substantially matt black appearance which is preferable in arrangements such as lighting rigs for theatrical concerts and performance applications where reflections can produce undesirable effects. In particular, for such applications, aluminium trussing is often painted with matt black paint, although this may still result in some glinting due to the paint being chipped and scratched during transit.

A truss is fabricated by securing basic assemblies of the type shown in *Figure 4* to nodes, such as node **501** shown in *Figure 5*. Nodes **501** are machined from high density aluminium alloy, or cast from a composite plastic and include a plurality of spherical voids **502**, each arranged to co-operate with a spigot **201** of a basic assembly to provide a conventional ball-joint configuration. In order to secure a basic assembly, epoxy glue is inserted within a spherical void using a glue gun **503** or similar device.

During the assembly process, basic assemblies are held at the required orientation with respect to a node **501** by means of a jig **601**. Jig **601** includes a plurality of channels **602**, each accurately positioned so as to hold a co-operating basic assembly in position with respect to a spherical void.

For a given nodal position, the angle at which a basic assembly extends from a spherical void is adjustable within a defined angle of adjustment. Adjustment of this type is facilitated by the presence of circular groove **205** in spigots **201**, thereby ensuring the movement of a basic

assembly is not unnecessarily limited due to interference between its spiral wound rod and a connecting node.

A node is shown in *Figure 7* forming part of a structural truss. In the example shown in *Figure 7*, basic assemblies **701** and **702** support high structural compressive loads and as such are fabricated from basic assemblies having a relatively large diameter. Furthermore, assemblies **701** and **702** could be constructed from rods wound so as to enhance their compressive strength. In addition, load carrying members are separated by intermediate basic assemblies **703** and **704** having a relatively smaller diameter. Thus, basic assemblies **701** to **704** are all secured to a node **705**, using a jig of the type shown in *Figure 6*.

Node **705** forms a component node of a structural truss of the type shown in *Figure 8*. The truss includes similar nodes **801, 802** and **803**. In its intended application, node **801** also supports major structural members conveying compressive forces. However, nodes **802** and **803** are connected to basic assemblies conveying tensile forces and, in a preferred embodiment, differently wound rods are used for these different applications.

Further nodes are used within the truss structure, with nodes **805** and **806** being configured to support three basic assemblies in relatively symmetrical orientations. Similarly, nodes **807** and **808** are configured to support two basic assemblies. Nodes **805, 806, 807** and **808** are also fabricated as termination nodes so as to facilitate connection to other trusses or other assemblies.

Having fabricated a truss of the type shown in *Figure 8*, it is possible for this truss to be employed in the fabrication of major structures and additional connecting members are used in order to allow trusses to be connected together. Furthermore, structures of alternative configuration may be created using a substantially similar connecting technologies. Consequently, large and complex structures may be fabricated essentially from the use of nodes and basic assemblies as described herein.

An alternative embodiment is shown in *Figure 9* in which assemblies **701** and **702** shown in *Figure 7* have been replaced by a continuous assembly **901**, onto which a saddle-shaped node **902** has been bonded thereto. Saddle node **902** includes spherical voids for receiving assemblies **903** and **904**, substantially similar to assemblies **703** and **704** shown in *Figure 7*.

A second alternative embodiment is shown in *Figure 10* in which each rod **1001**, **1002** and **1003** is bonded directly to tapered extensions **1004**, **1005** and **1006** respectively of a node **1007**. In this configuration, there is no requirement for ball-end spigots but a disadvantage of the arrangement is that there is no possibility of relative movement between the rods and the nodes which may result in constructional stresses being introduced during the construction of a truss.

A third alternative embodiment is shown in *Figure 11* in which rods **1101**, **1102** and **1103** are connected to non-tapered extensions **1104**, **1105** and **1106** respectively of a node **1107** via threaded collets **1108**. A tapered end **1109** of collet **1108** is secured within rod **1101** in a fashion substantially similar to the securing of a ball-end spigot **204**. The collet is then placed over the extension **1104** and held firmly thereon by the application of locking nut **1110**.

Claims

1. A structural truss or frame having a plurality of longitudinal support members held together by a plurality of nodal members, wherein

each of said support members is constructed from a fibrous composite material; and

said nodal members are configured to receive said support members.

2. A truss according to claim 1, wherein said support members have spigots attached thereto and said spigots are configured to be received by said nodal members.

3. A truss according to claim 2, wherein said spigots are ball-ended and said ball-ends are received within spherical voids of said nodal members.

4. A truss according to claim 1, wherein said support members are substantially circular in cross-section.

5. A truss according to claim 4, wherein said circular support members are hollow tubes.

6. A truss according to claim 4, wherein said hollow tubes are constructed from spiral wound carbon fibre.

7. A truss according to claim 1, wherein said fibrous composite material includes carbon fibre.

8. A truss according to claim 1, wherein said fibrous composite material includes epoxy resin.

9. A truss according to claim 2, wherein said locatable spigots are of a metallic construction.

10. A truss according to claim 9, wherein said metallic spigots include a taper insertable into a hollow support member.

11. A truss according to claim 10, wherein said taper is of substantially circular cross-section.

12. A truss according to claim 10, wherein said taper is angled and co-operates with a similar angled taper on inside faces of said support members.

13. A truss according to claim 12, wherein said taper is glued against an inside face of said support member.

14. A truss according to claim 2, wherein said spigots include a circumferencial groove cut between said taper and said insert portion.

15. A truss according to claim 13, wherein said insert portions are secured within a spherical void by epoxy resin.

16. A method of assembling a truss, comprising steps of

winding carbon-fibres onto a mandrill with a resin to produce solid rods;

cutting said rods to predetermined lengths; and

securing said rods by nodal members such that some of said rods are placed in compression while some of said rods are placed in tension when said truss is in use.

17. A method according to claim 16, wherein the winding of said rods is adjusted in dependence upon whether said rods are to be placed in tension or compression.

The Patent Office

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Application No: GB 9806435.5
Claims searched: 1-17

Examiner: B.J.Buchanan
Date of search: 21 August 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): E1D: CA1079, LEB, LEF, LFB, LFF

Int Cl (Ed.6): E04B, E04C

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	WO97/28327	University of California (See esp. Page 5, line 35 - page 6, line 6 & Figures 11A - 16B at least.)	1,4,7,8
X	US5357729	Schütze (See esp. Col. 3 lines 4 - 24)	1,4-8,16,17
A	US4384802	Shell Oil Company	
A	US4020202	Maschinenfabrik Augsburg-Nurnberg AG	

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